

# Digital Design & Computer Arch.

## Lecture 2a: Course Goals & Logistics

Prof. Onur Mutlu

ETH Zürich

Spring 2020

21 February 2020

# The Lecture Was Slightly Different When I Was at CMU

# What Is This?





# Answer: Masterpiece of A Famous Architect

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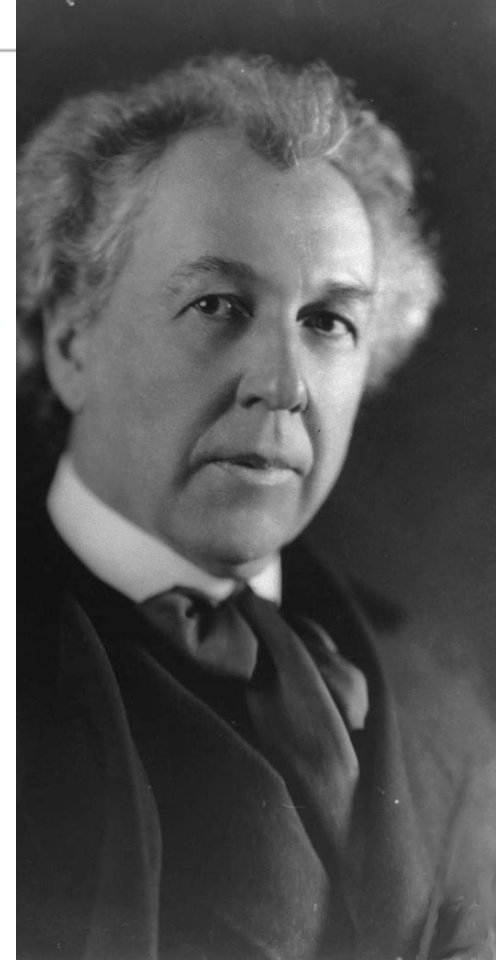
## Fallingwater

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From Wikipedia, the free encyclopedia

**Fallingwater** or **Kaufmann Residence** is a house designed by architect [Frank Lloyd Wright](#) in 1935 in rural [southwestern Pennsylvania](#), 43 miles (69 km) southeast of [Pittsburgh](#).<sup>[4]</sup> The home was built partly over a waterfall on [Bear Run](#) in the Mill Run section of [Stewart Township, Fayette County, Pennsylvania](#), in the [Laurel Highlands](#) of the [Allegheny Mountains](#).

[Time](#) cited it after its completion as Wright's "most beautiful job";<sup>[5]</sup> it is listed among [Smithsonian's](#) Life List of 28 places "to visit before you die."<sup>[6]</sup> It was designated a [National Historic Landmark](#) in 1966.<sup>[3]</sup> In 1991, members of the [American Institute of Architects](#) named the house the "best all-time work of American architecture" and in 2007, it was ranked twenty-ninth on the [list of America's Favorite Architecture](#) according to the AIA.



Find The Differences of  
This and That

# This

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# That

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# A Key Question

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- How was Wright able to design his masterpiece?
- Can have many guesses
  - ❑ (Ultra) hard work, perseverance, dedication (over decades)
  - ❑ Experience
  - ❑ Creativity, Out-of-the-box thinking
  - ❑ A good understanding of past designs
  - ❑ Good judgment and intuition
  - ❑ Strong skill combination (math, architecture, art, engineering, ...)
  - ❑ Funding (\$\$\$\$), luck, initiative, entrepreneurialism
  - ❑ Strong understanding of and commitment to fundamentals
  - ❑ Principled design
  - ❑ ...
- (You will be exposed to and hopefully develop/enhance many of these skills in this course)



# A Quote from The Architect Himself

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- “architecture [...] based upon **principle**, and not upon **precedent**”



# A Principled Design

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## Organic architecture

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From Wikipedia, the free encyclopedia

**Organic architecture** is a [philosophy](#) of [architecture](#) which promotes harmony between human habitation and the natural world through design approaches so sympathetic and well integrated with its site, that buildings, furnishings, and surroundings become part of a unified, interrelated composition.

A well-known example of organic architecture is [Fallingwater](#), the residence Frank Lloyd Wright designed for the Kaufmann family in rural Pennsylvania. Wright had many choices to locate a home on this large site, but chose to place the home directly over the waterfall and creek creating a close, yet noisy dialog with the rushing water and the steep site. The horizontal striations of stone masonry with daring [cantilevers](#) of colored beige concrete blend with native rock outcroppings and the wooded environment.

# A Key Question

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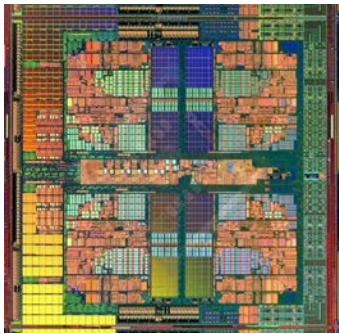
# Takeaways

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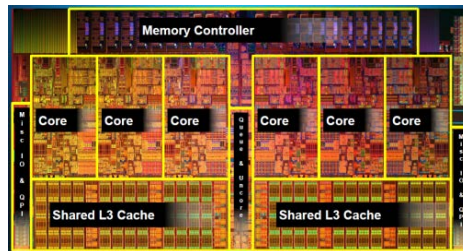
- It all starts from the basic building blocks and design principles
- And, knowledge of how to use & apply them
- Underlying technology might change (e.g., steel vs. wood)
  - but methods of taking advantage of technology bear resemblance
  - methods used for design depend on the principles employed

# The Same Applies to Processor Chips

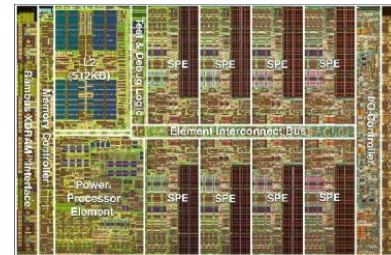
- There are **basic building blocks** and **design principles**



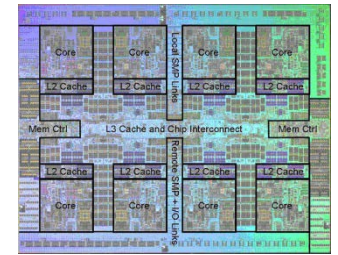
AMD Barcelona  
4 cores



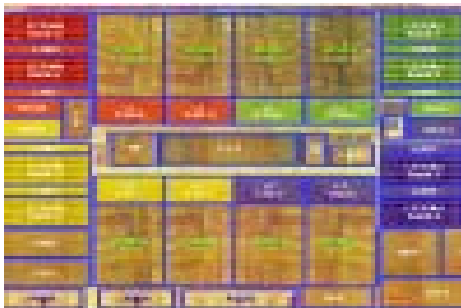
Intel Core i7  
8 cores



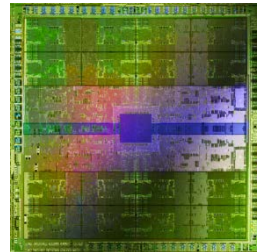
IBM Cell BE  
8+1 cores



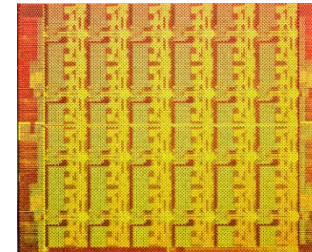
IBM POWER7  
8 cores



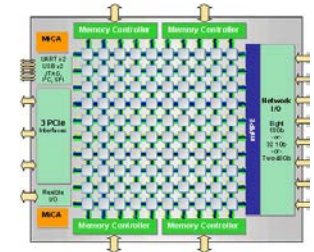
Sun Niagara II  
8 cores



Nvidia Fermi  
448 "cores"



Intel SCC  
48 cores, networked



Tiler TILE Gx  
100 cores, networked

# The Same Applies to Computing Systems

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- There are **basic building blocks** and **design principles**





# The Same Applies to Computing Systems

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- There are **basic building blocks** and **design principles**



# Different Platforms, Different Goals





# Different Platforms, Different Goals

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# Different Platforms, Different Goals

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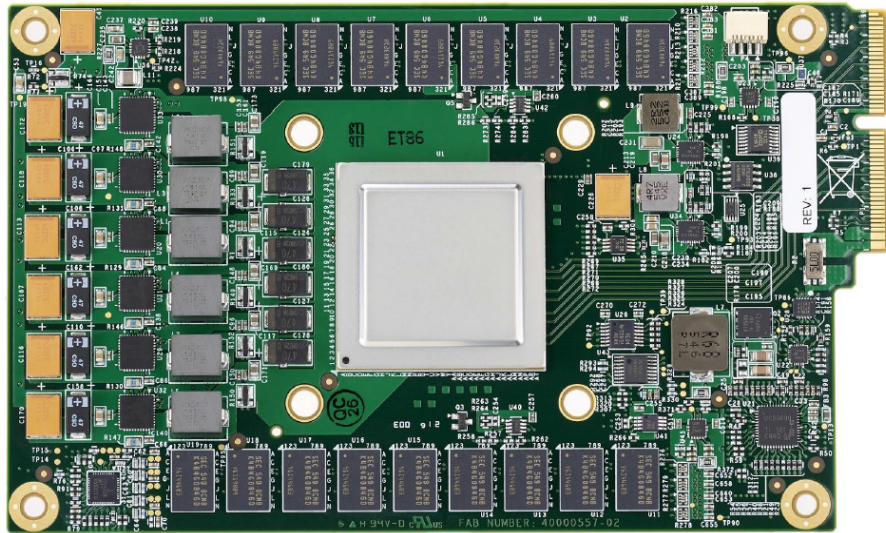
# Different Platforms, Different Goals

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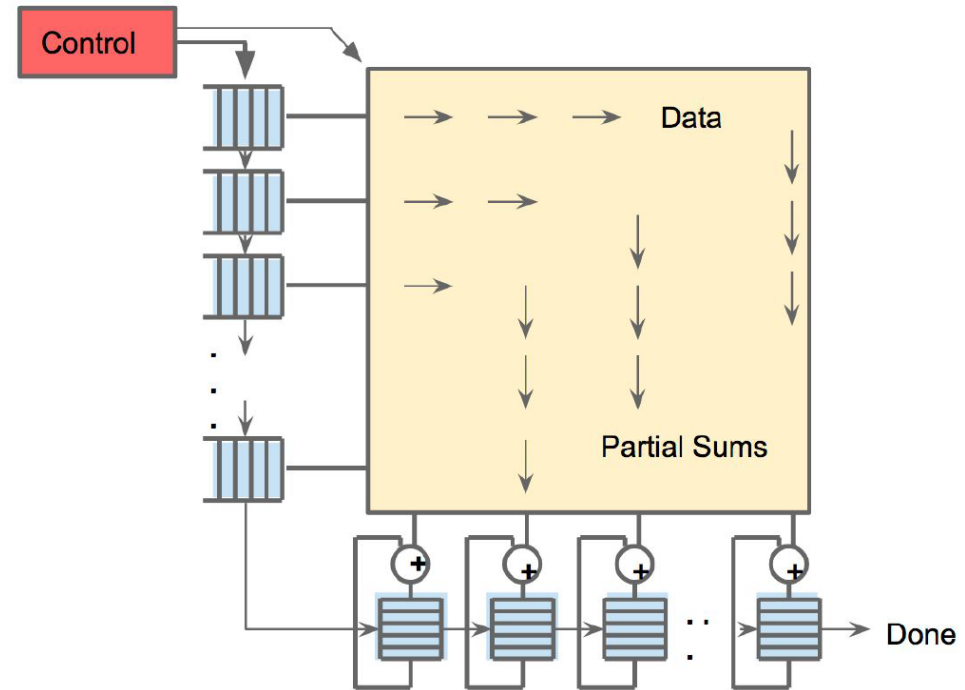


Jack Dongarra

# Different Platforms, Different Goals



**Figure 3.** TPU Printed Circuit Board. It can be inserted in the slot for an SATA disk in a server, but the card uses PCIe Gen3 x16.



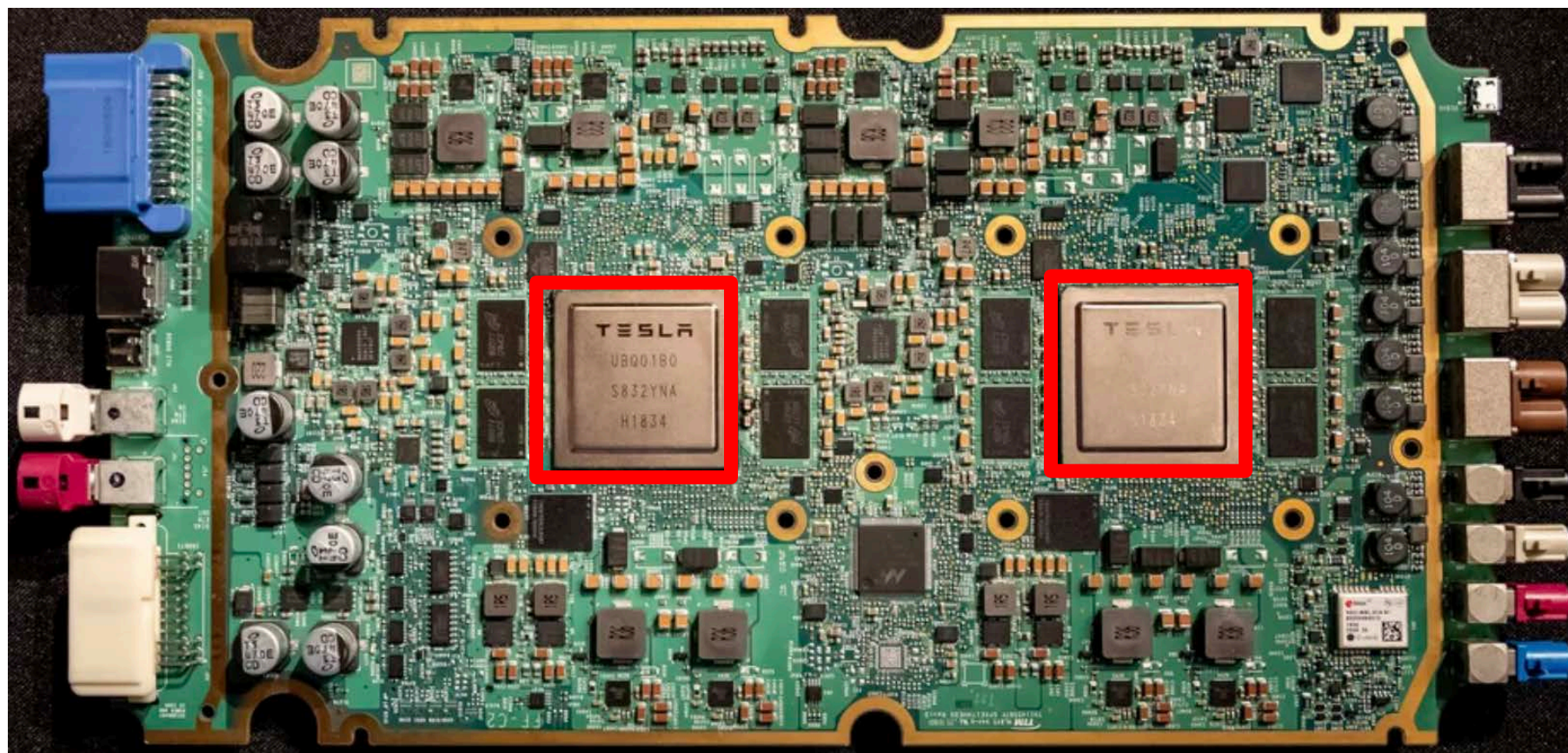
**Figure 4.** Systolic data flow of the Matrix Multiply Unit. Software has the illusion that each 256B input is read at once, and they instantly update one location of each of 256 accumulator RAMs.

Jouppi et al., “In-Datacenter Performance Analysis of a Tensor Processing Unit”, ISCA 2017.



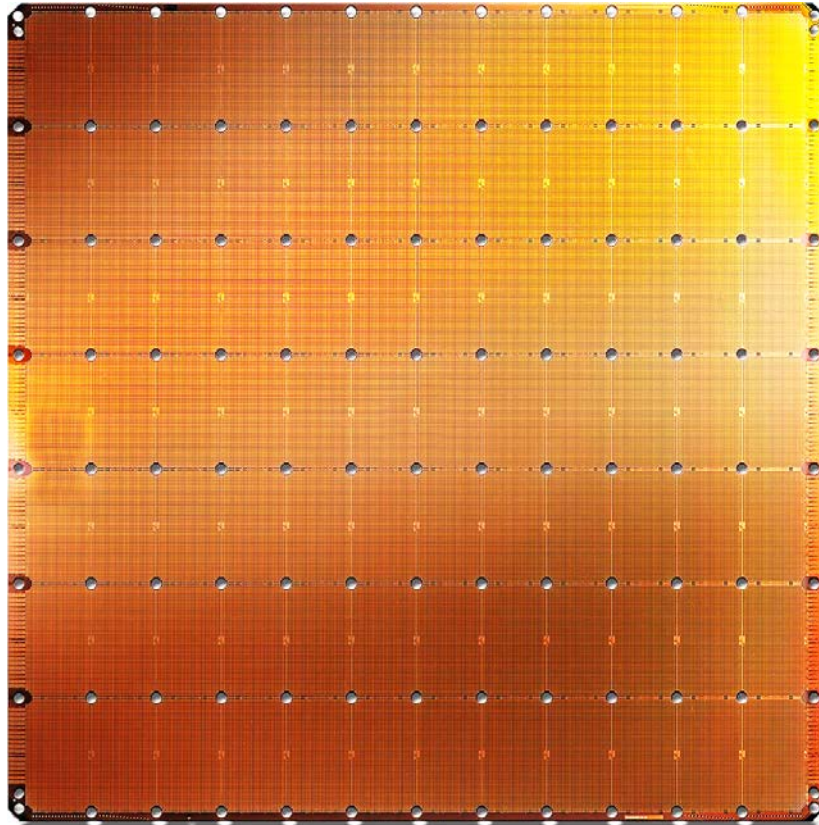
# Different Platforms, Different Goals

- ML accelerator: 260 mm<sup>2</sup>, 6 billion transistors, 600 GFLOPS GPU, 12 ARM 2.2 GHz CPUs.
- Two redundant chips for better safety.



# Different Platforms, Different Goals

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## **Cerebras WSE**

1.2 Trillion transistors  
46,225 mm<sup>2</sup>

- The largest ML accelerator chip
- 400,000 cores



## **Largest GPU**

21.1 Billion transistors  
815 mm<sup>2</sup>

NVIDIA TITAN V

<https://www.anandtech.com/show/14758/hot-chips-31-live-blogs-cerebras-wafer-scale-deep-learning>

<https://www.cerebras.net/cerebras-wafer-scale-engine-why-we-need-big-chips-for-deep-learning/>

# Basic Building Blocks

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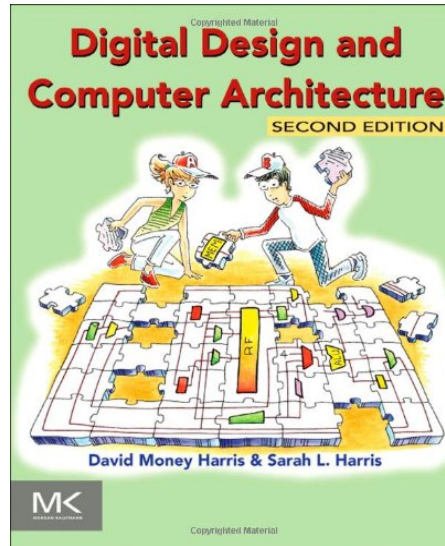
- Electrons
- Transistors
- Logic Gates
- Combinational Logic Circuits
- Sequential Logic Circuits
  - Storage Elements and Memory
- ...
- Cores
- Caches
- Interconnect
- Memories
- ...



# Reading Assignments for This Week

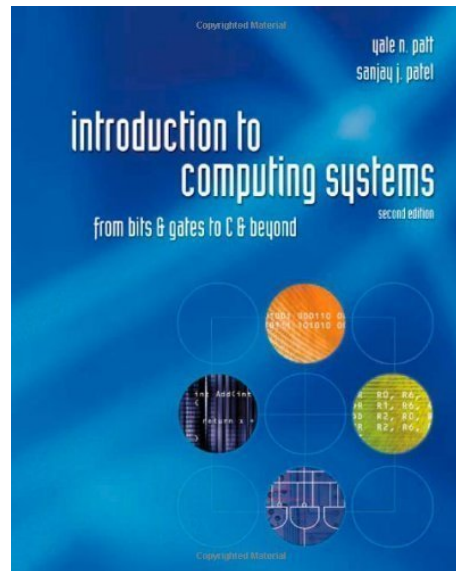
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- Chapter 1 in Harris & Harris



- Supplementary Lecture Slides on Binary Numbers

- Chapters 1-2 in Patt and Patel



# Major High-Level Goals of This Course

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- In Digital Circuits & Computer Architecture
- Understand the basics
- Understand the principles (of design)
- Understand the precedents
- Based on such understanding:
  - learn how a modern computer works underneath
  - evaluate tradeoffs of different designs and ideas
  - implement a principled design (a simple microprocessor)
  - learn to systematically debug increasingly complex systems
  - Hopefully enable you to develop novel, out-of-the-box designs
- The focus is on basics, principles, precedents, and how to use them to create/implement good designs

# Why These Goals?

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- Because you are here for a Computer Science degree
- **Regardless of your future direction**, learning the principles of digital design & computer architecture will be useful to
  - ❑ design better hardware
  - ❑ design better software
  - ❑ design better systems
  - ❑ make better tradeoffs in design
  - ❑ understand why computers behave the way they do
  - ❑ solve problems better
  - ❑ think “in parallel”
  - ❑ think critically
  - ❑ ...



# Course Info and Logistics

# Course Info: Instructor

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## ■ Onur Mutlu

- ❑ Professor @ ETH Zurich CS, since September 2015 (started May 2016)
- ❑ Strecker Professor @ Carnegie Mellon University ECE/CS, 2009-2016, 2016-...
- ❑ PhD from UT-Austin, worked at Google, VMware, Microsoft Research, Intel, AMD
- ❑ <https://people.inf.ethz.ch/omutlu/>
- ❑ [omutlu@gmail.com](mailto:omutlu@gmail.com) (Best way to reach me)
- ❑ Office hours: By appointment (email me)

## ■ Research and Teaching in:

- ❑ Computer architecture, computer systems, bioinformatics, hardware security
- ❑ Memory and storage systems
- ❑ Hardware security
- ❑ Fault tolerance
- ❑ Hardware/software cooperation
- ❑ Genome analysis and application-algorithm-hardware co-design
- ❑ ...

# Course Info: Lecturer & PhD Assistants

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- Head Assistant
  - Dr. Juan Gómez Luna
  
- Vice-Head Assistant
  - Hasan Hassan
  
- Lecturer
  - Dr. Frank Gurkaynak
  
- (Other) Key Assistants and Guest Lecturers
  - Dr. Mohammed Alser
  - Dr. Lois Orosa
  - Dr. Jawad Haj-Yahya
  - Dr. Jisung Park



# Course Info: PhD Assistants

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- (Other) Key Assistants and Guest Lecturers (cont.)
  - ❑ Minesh Patel
  - ❑ Giray Yaglikci
  - ❑ Can Firtina
  - ❑ Geraldo De Oliveira Junior
  - ❑ Rahul Bera
  - ❑ Konstantinos Kanellopoulos

# Course Info: Student Assistants

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- Roknoddin Azizibarzoki
- Tim Fischer
- Lukas Gygi
- Leo Horné
- Lara Lazier
- Artur Melo
- Chris Mnuk
- Nathan Neike
- Arpan Prasad
- Nina Richter
- João Dinis Sanches Ferreira
- Taha Shahroodi
- Roberto Starc

# Course Info: Lab Assistants (I)

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- Tuesday 15-17

- TBD

- Wednesday 15-17

- TBD



# Course Info: Lab Assistants (II)

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- Friday 8-10

- TBD

- Friday 10-12

- TBD

# If You Need Help

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- Post your question on Q&A Forum (soon announced)
  - **Preferred** for **technical** questions
  
- Write an e-mail to:
  - [digitaltechnik@lists.inf.ethz.ch](mailto:digitaltechnik@lists.inf.ethz.ch)
  - The instructor and all assistants will receive this e-mail
  
- Come to office hours (CAB H 31.2)
  - Monday 1:30pm-2:30pm
  - Tuesday: 5pm-6pm
  - Wednesday: 10am-11am
    - We might need to change the room due to space limitations. In that case, we will announce it in advance

# Where to Get Up-to-date Course Info?

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- Website:
  - ❑ <https://safari.ethz.ch/digitaltechnik/>
  - ❑ Lecture slides and videos
  - ❑ Readings
  - ❑ Lab information
  - ❑ Course schedule, handouts, FAQs
  - ❑ Software
  - ❑ Plus other useful information for the course
  - ❑ Check frequently for announcements and due dates
  - ❑ This is your single point of access to all resources
- Your ETH Email
- Lecturers and Teaching Assistants



# Lecture and Lab Times and Policies

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## ■ Lectures:

- ❑ Thursday and Fridays, 13:15-15:00
- ❑ HG F7 (F5 overflow)
- ❑ Attendance is for your benefit and is therefore important
- ❑ Some days, we will have guest lectures and exercise sessions

## ■ Lab sessions:

- ❑ See online
- ❑ You should definitely attend the lab sessions
  - In-class evaluation (70%) and mandatory lab reports (30%)
- ❑ Labs will start on February 28th
- ❑ Lab information and handouts are here:
  - <https://safari.ethz.ch/digitaltechnik/spring2020/doku.php?id=labs>

# Lab Organization

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## ■ Groups

- ❑ Choose your **preferred group** in Moodle
  - <https://moodle-app2.let.ethz.ch/mod/choicegroup/view.php?id=412173>
  - Due **24.02.2020 at 11:59pm**
- ❑ Choose your **partner**
  - <https://moodle-app2.let.ethz.ch/mod/feedback/view.php?id=418396>
  - Due **24.02.2020 at 11:59pm**

## ■ Lab grades from previous years

- <https://moodle-app2.let.ethz.ch/mod/choice/view.php?id=412175>
- Choose among (due **26.02.2020 at 11:59pm**):
  - ❑ 1) I will use my lab grades from previous years, and I won't do the labs this year
  - ❑ 2) I will use my lab grades from previous years, but I will do the labs this year
  - ❑ 3) I won't use my lab grades from previous years. I will do the labs this year

# Final Exam

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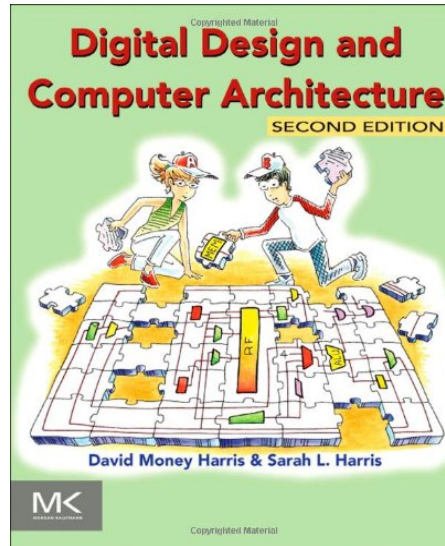
- 180-minute written exam
  - Find examination rules in Course Catalogue
  - Also in the first page of previous exams
    - <https://safari.ethz.ch/digitaltechnik/spring2020/doku.php?id=exams>
  - Some exam questions are similar to questions in Optional HWs
    - Optional HWs are optional, but highly recommended



# Reading Assignments for This Week

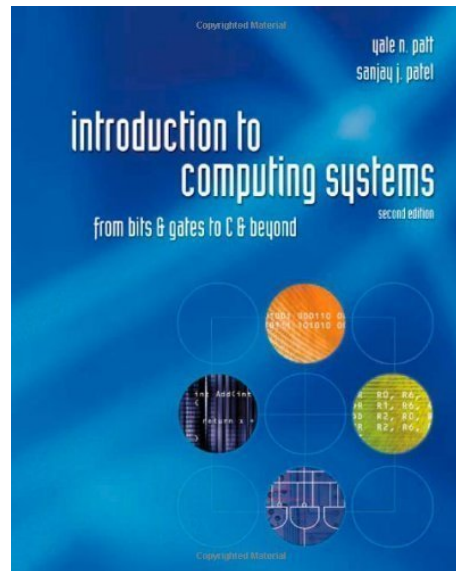
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- Chapter 1 in Harris & Harris



- Supplementary Lecture Slides on Binary Numbers

- Chapters 1-2 in Patt and Patel



# Reading Assignments for Next Week

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- Combinational Logic chapters from both books
  - Patt and Patel, Chapter 3
  - Harris and Harris, Chapter 2
  
- Check course website for all future readings
  - Required
  - Recommended
  - Mentioned

# Digital Design & Computer Arch.

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